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# Shape from Profiles

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Department of Engineering

# Motivation

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# 3D model acquisition

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# Perspective

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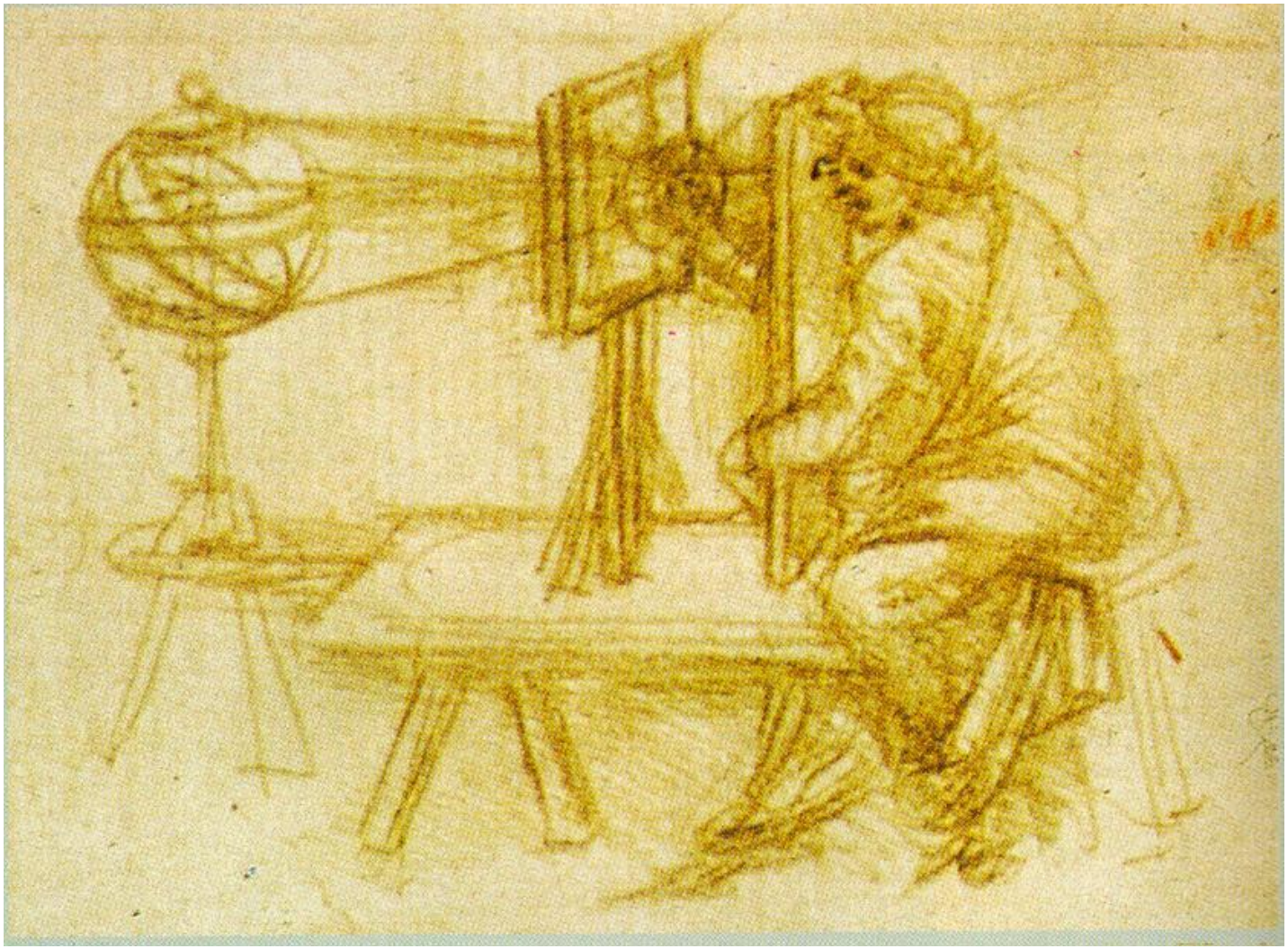

# Overview

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- Review of reconstruction from profiles
  - Tracking with B-spline snakes
  - Epipolar geometry
- Review of recovery of motion from profiles
  - Epipolar geometry from frontiers
  - Circular or turntable motion
- Realtime practical system
  - Trivial initialization using circular motion
  - Addition of arbitrary uncalibrated views
  - Octree generation and voxel carving

# Shape from Profile

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# Singular Profiles

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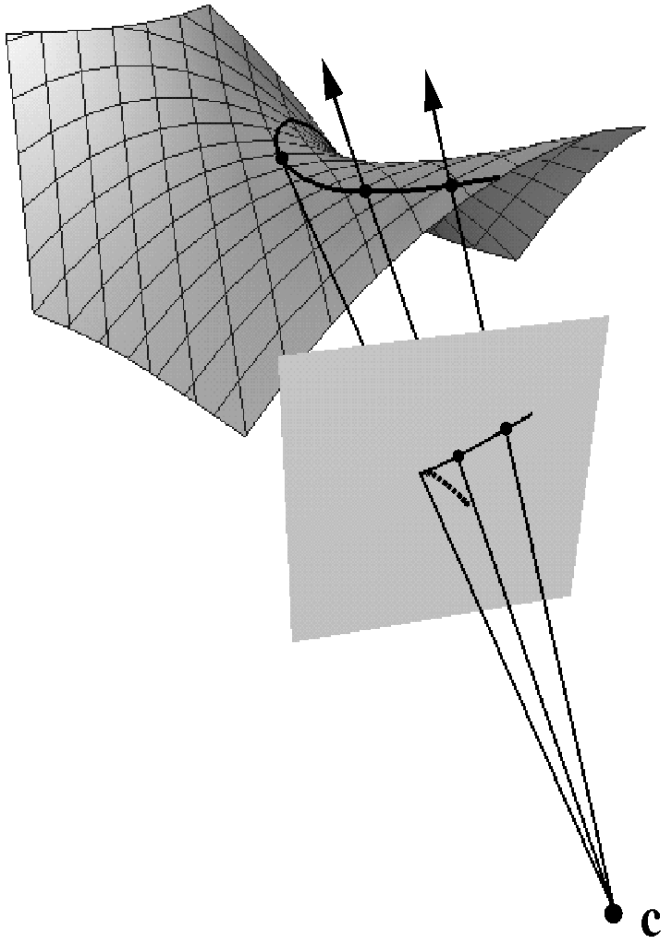

# Swallowtail visual event

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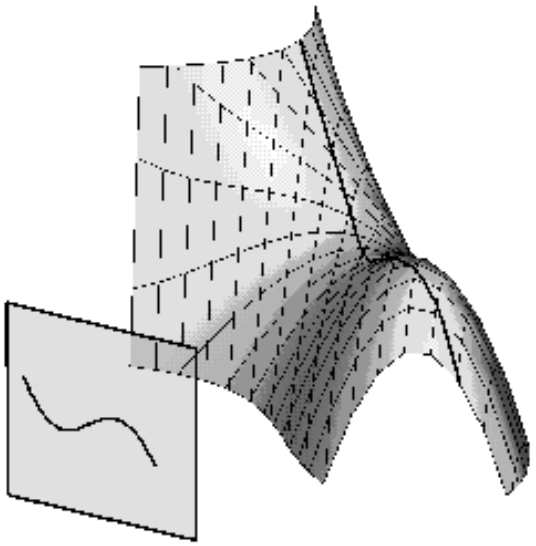

Ray has 2-point contact with surface at contour generator

# Swallowtail visual event

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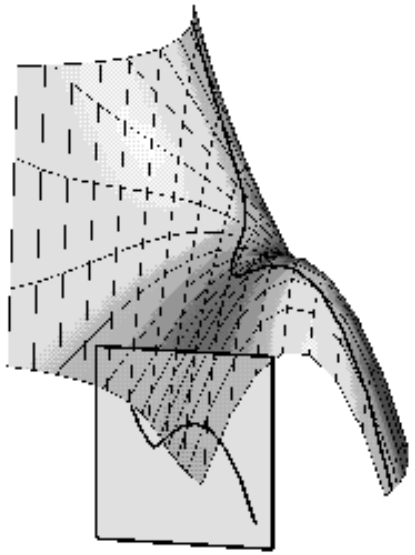

Ray has 4-point contact with surface at flecnodal point

# Swallowtail visual event

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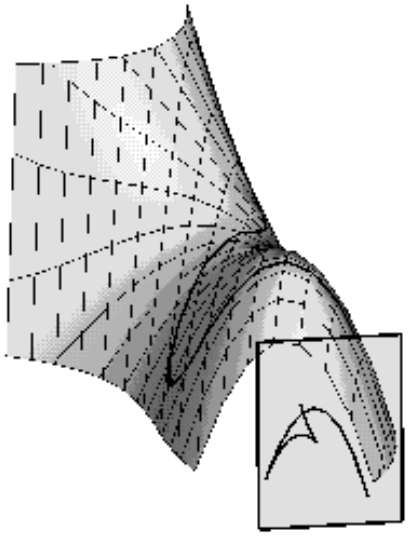

Ray has 3-point contact with surface at cusps of apparent contours

# Tracking profiles

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# Epipolar Parameterisation

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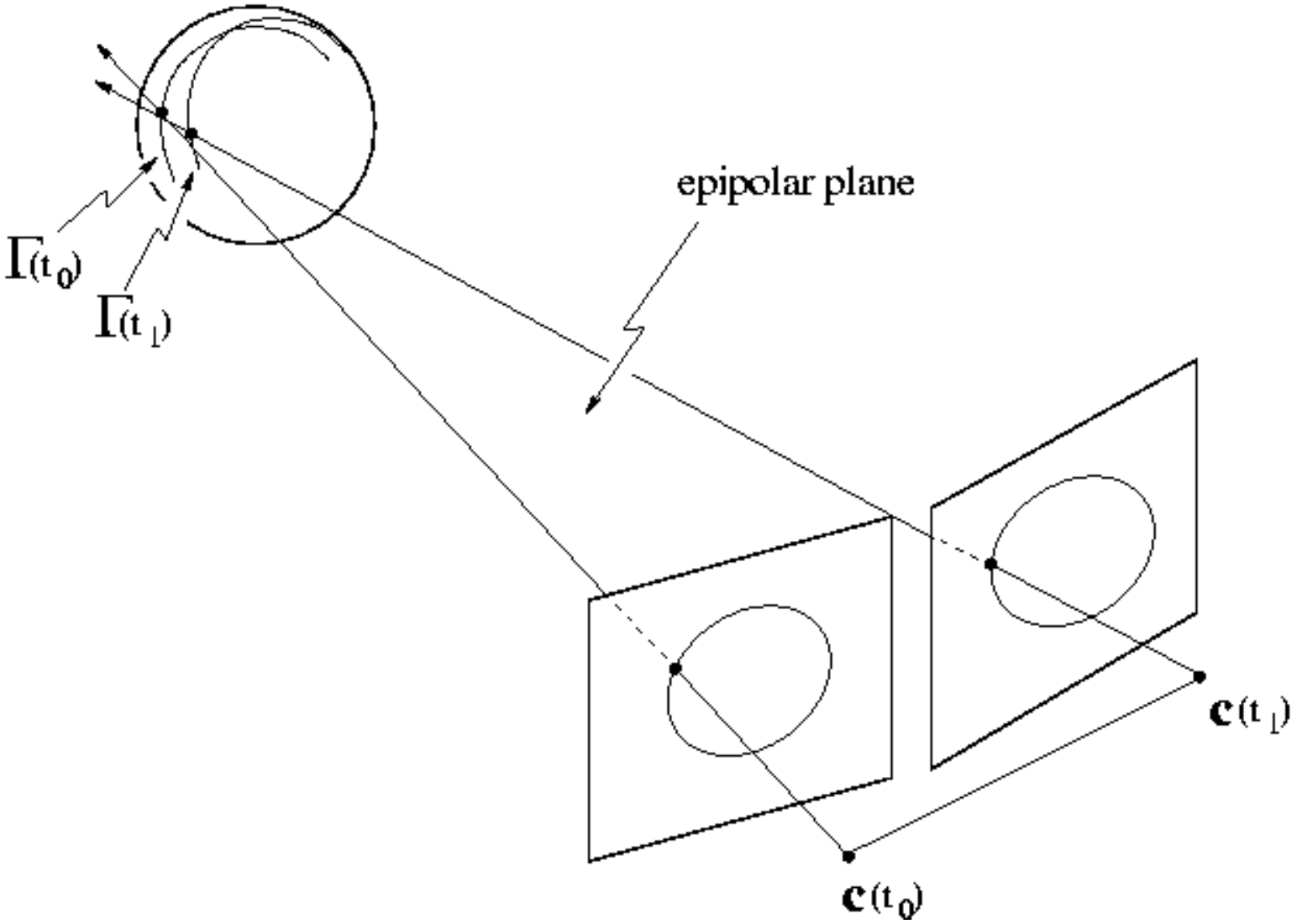

# Reconstruction of surfaces

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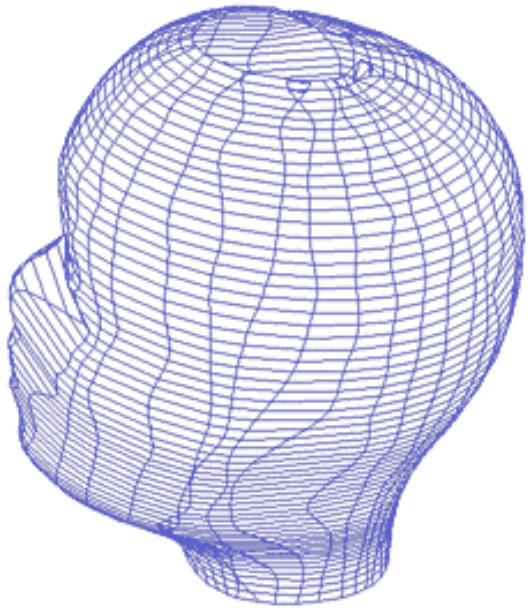

# Stereo vision

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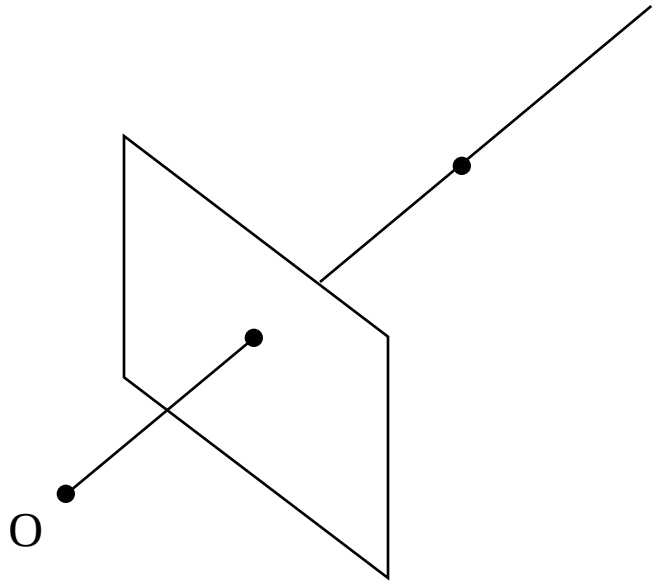

# Stereo vision

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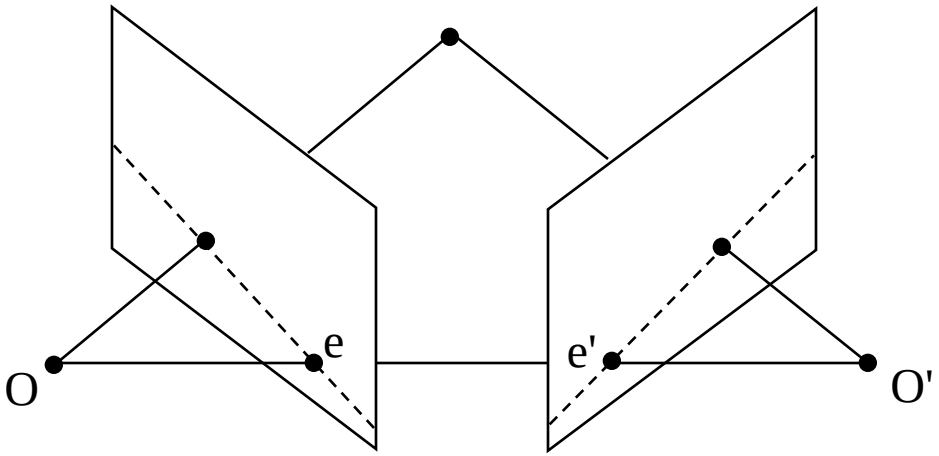

# Epipolar geometry

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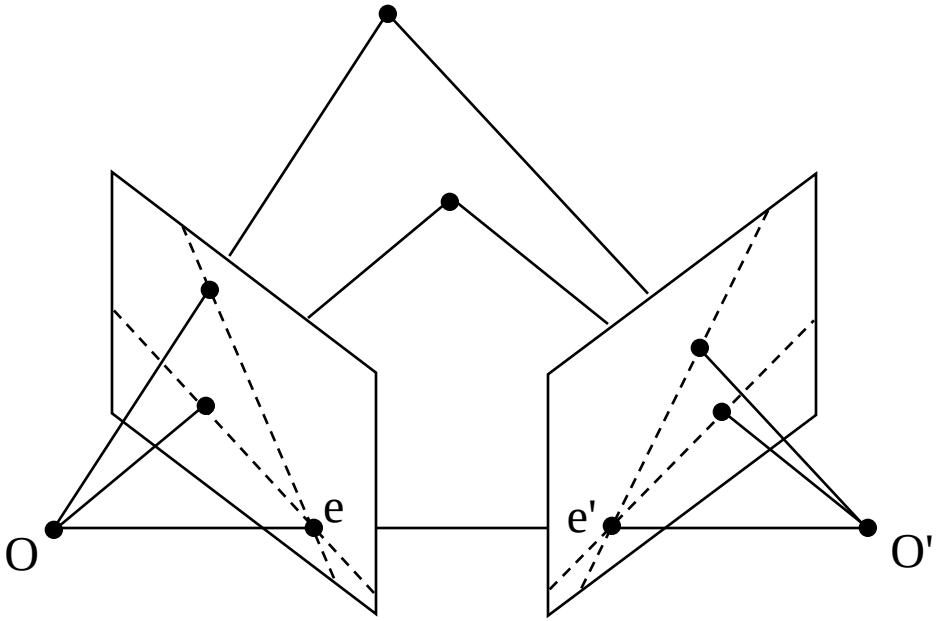


$$\begin{bmatrix} u & v & 1 \end{bmatrix} \begin{bmatrix} & F & \\ & & \\ & & \end{bmatrix} \begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = 0$$

# Epipolar geometry

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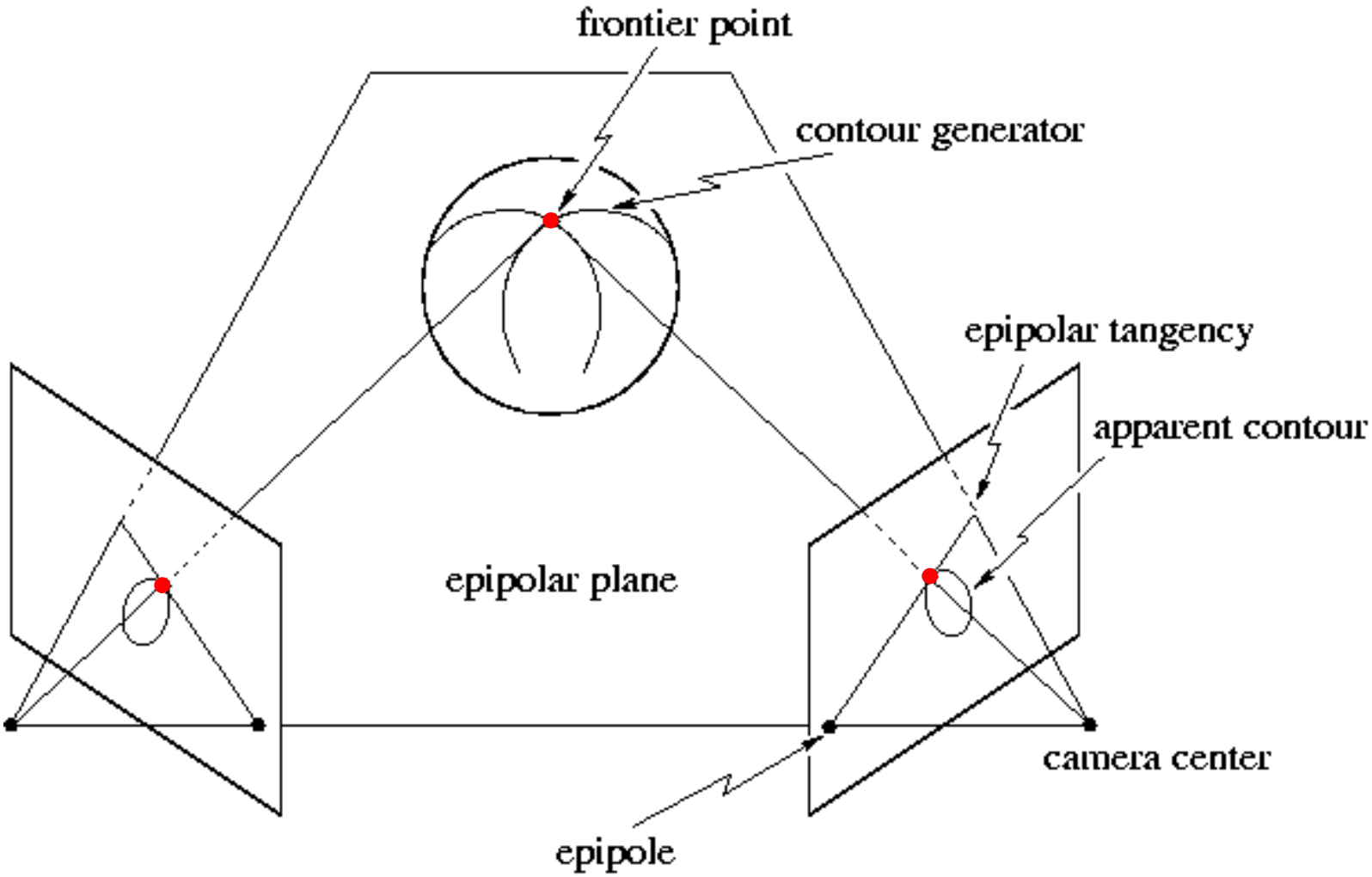

# Previous Work

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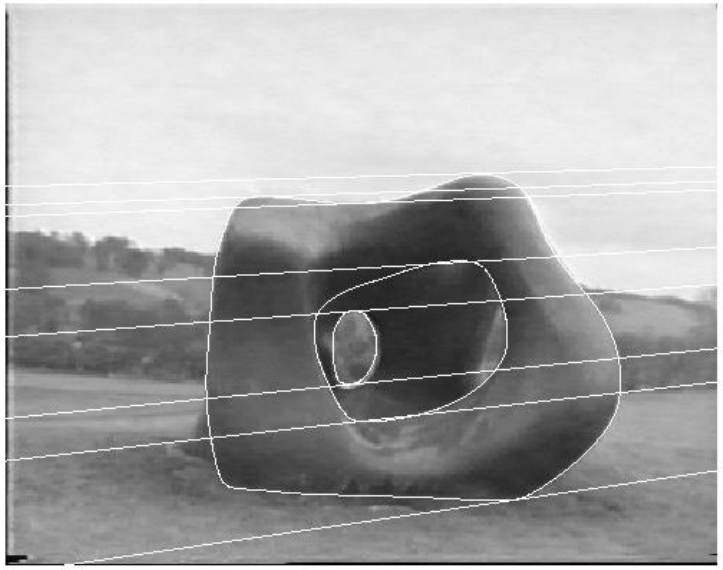
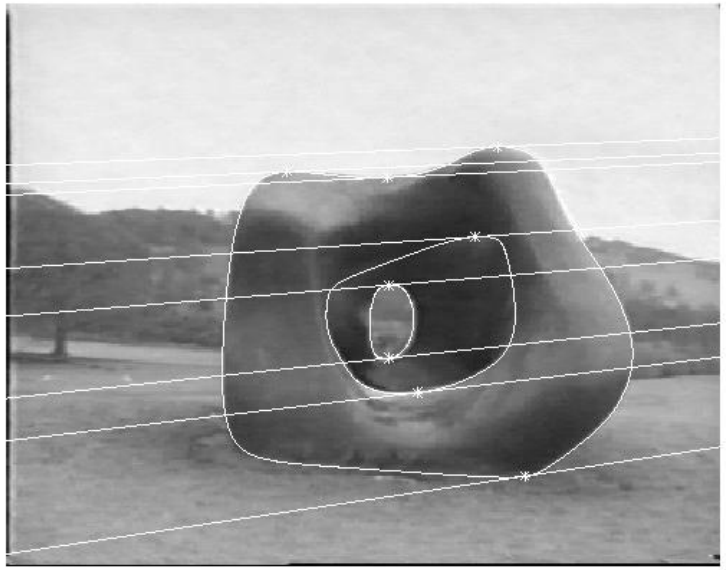
- Epipolar Geometry - **F**:
  - General motion (7 dof):
    - ≥ 7 epipolar tangencies.





# Previous Work

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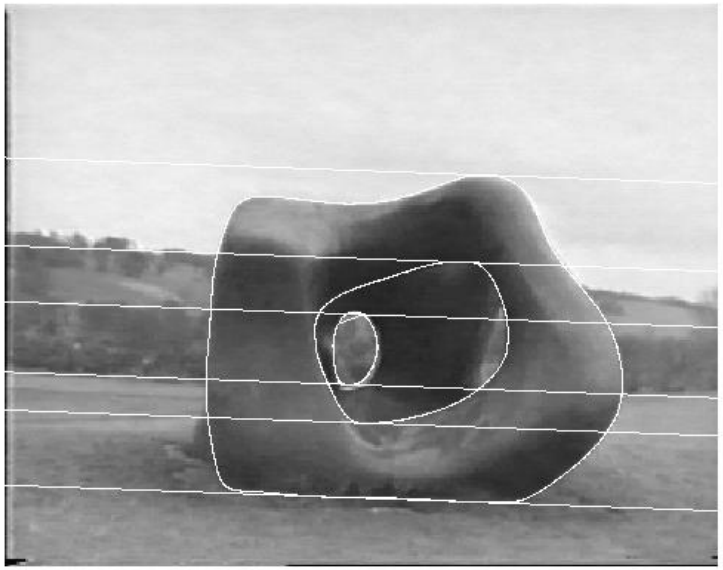
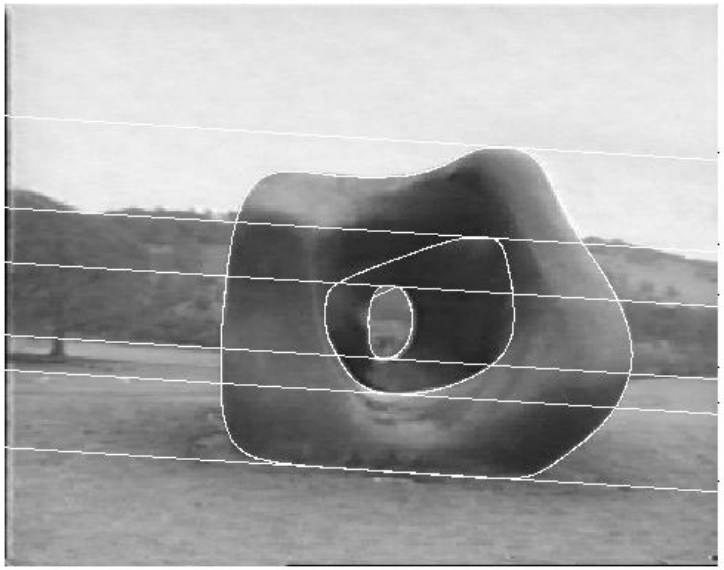
- Epipolar Geometry - **F**:
  - Affine approximation (4 dof):
    - ≥ 4 epipolar tangencies.





# Previous Work

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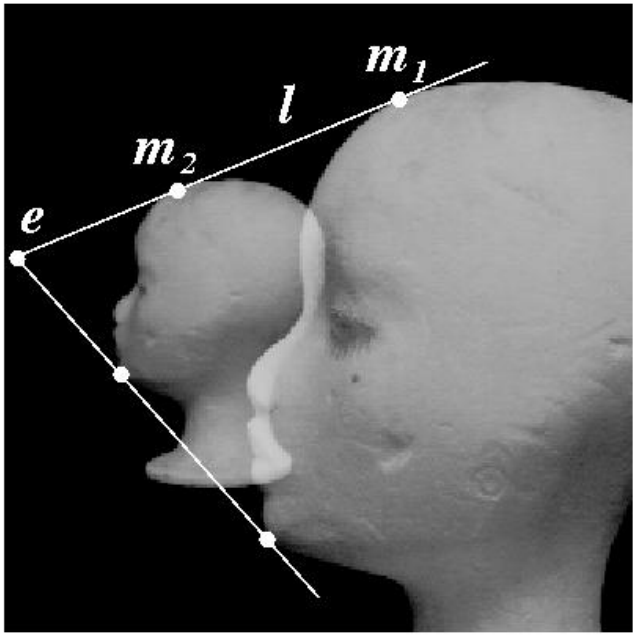
- Epipolar Geometry - **F**:
  - Linear motion (2 dof):
    - ≥ 2 epipolar tangencies.



# Practical solution

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- Epipolar Geometry - **F**:
  - Circular Motion (6 dof):
    - ≥ 2 epipolar tangencies.

# Surfaces of Revolution

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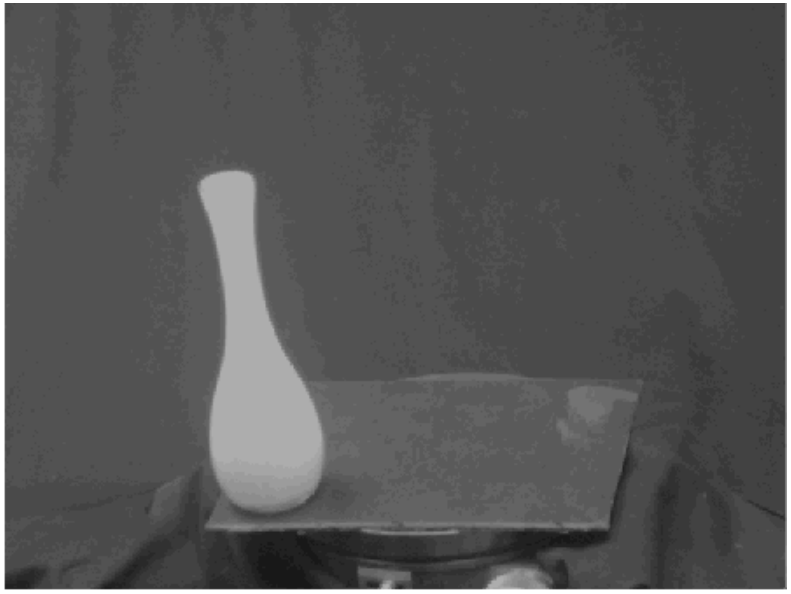

# Symmetry Transformations

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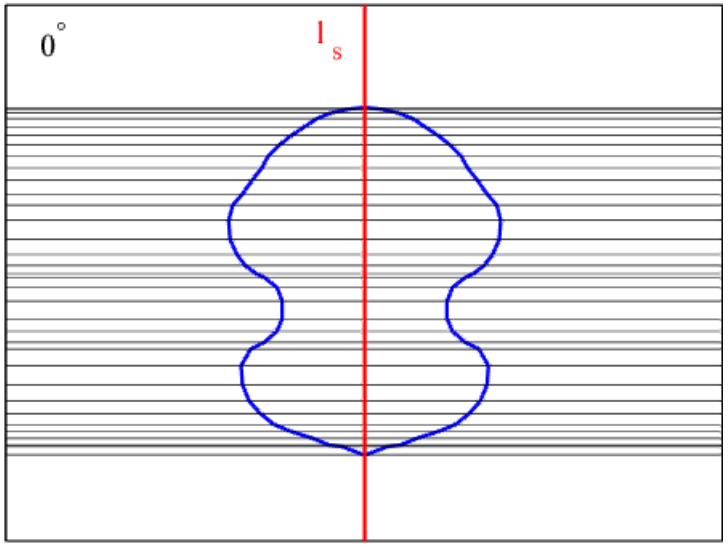
$$\mathbf{W} = \mathbf{I} - 2\frac{\mathbf{v}_x \mathbf{l}_s^{\mathrm{T}}}{\mathbf{v}_x^{\mathrm{T}} \mathbf{l}_s}$$



# Epipolar Geometry

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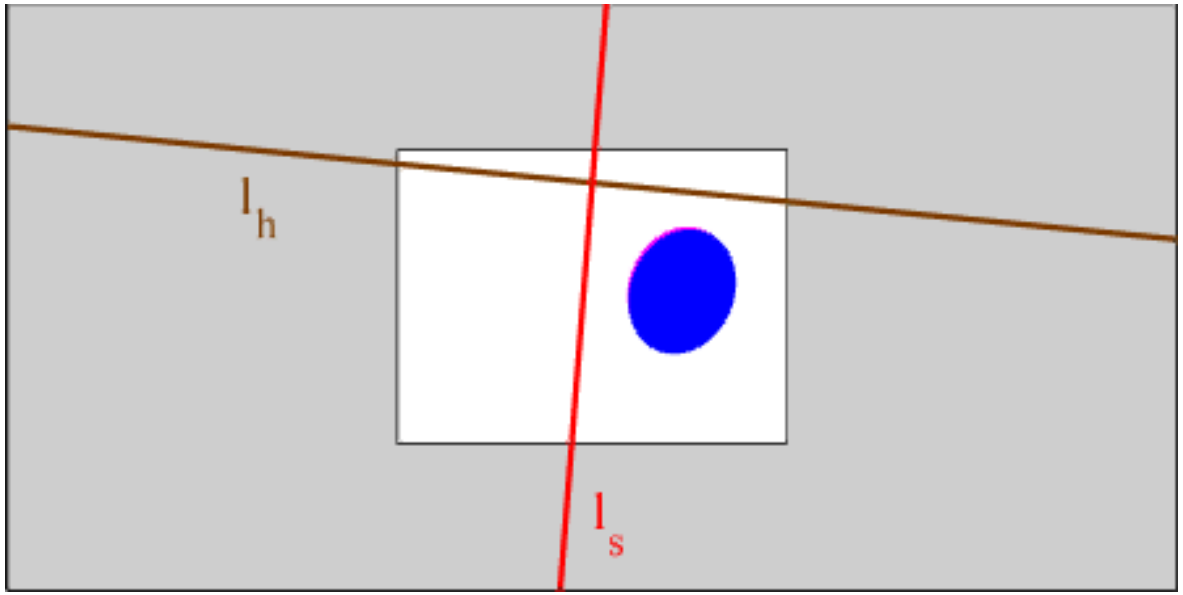
- For circular motion:
  - fixed entities:
    - image of screw axis, horizon, $\mathbf{v}_x$ : 5 d.o.f.
  - epipoles and epipolar lines related by $\mathbf{W}$

$$\mathbf{F} = [\mathbf{e}]_\times \mathbf{W}$$



# Epipolar Geometry

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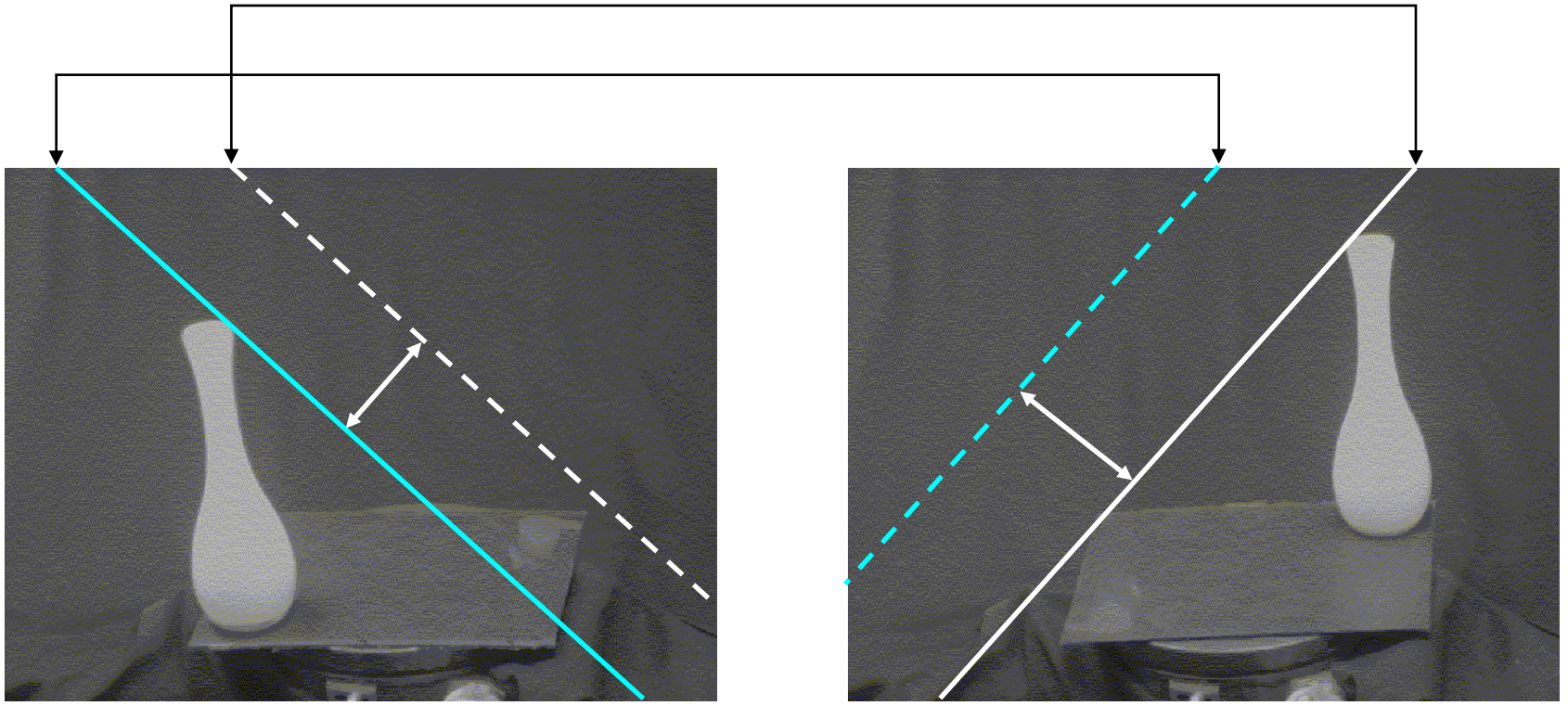
Geometric error of transferred epipolar lines:



# Epipolar Geometry

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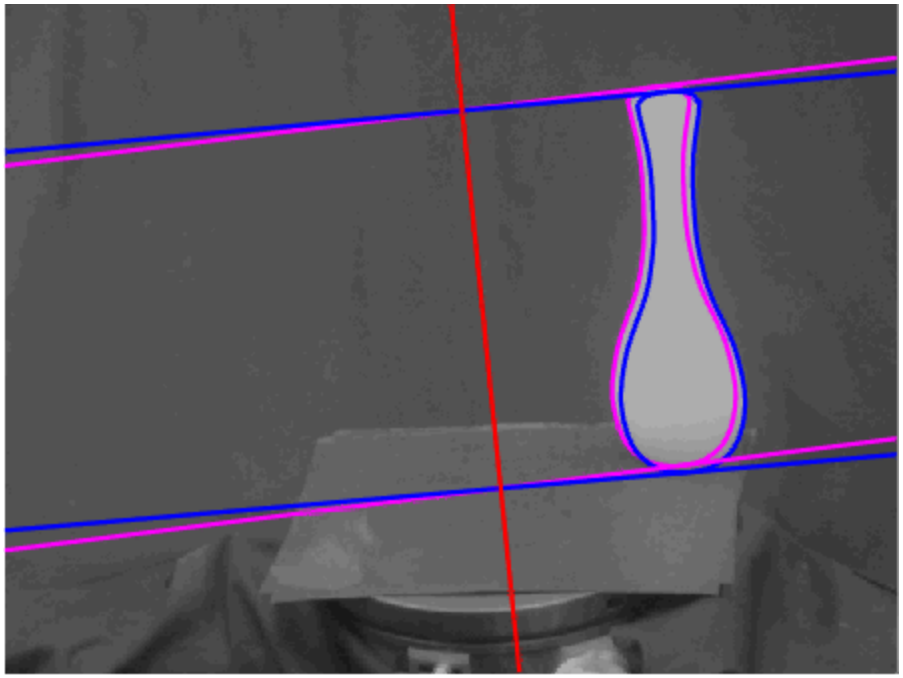
- Correspondent epipolar tangents:
  - related by $\mathbf{W}$, intersect at image of screw axis.
- Epipolar tangents in same image:
  - intersect at the epipole.



# Reparameterization of **F**

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$$\mathbf{F} = [\mathbf{v}_x]_\times + \mu \tan\frac{\theta}{2}\left(\mathbf{l}_s\mathbf{l}_h^T + \mathbf{l}_h\mathbf{l}_s^T\right)$$

- $v_x$ and $l_s$ - recovered from the harmonic homology;
- $l_h$ - recovered from epipolar constraints.
- relative scale factor

# Epipolar Geometry

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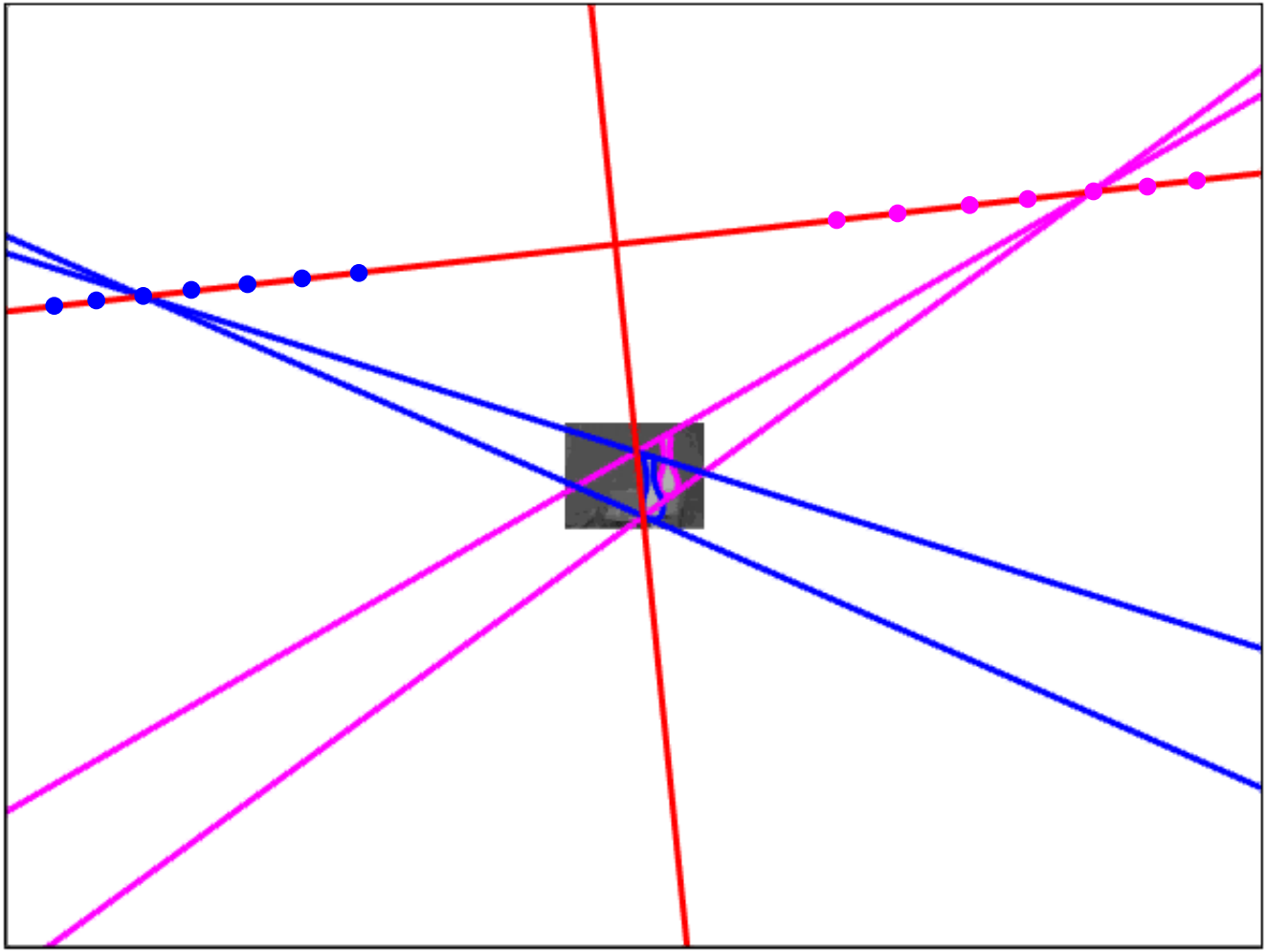

# Recovery of motion

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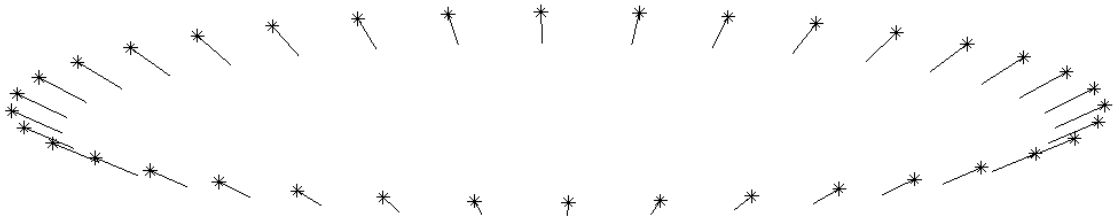

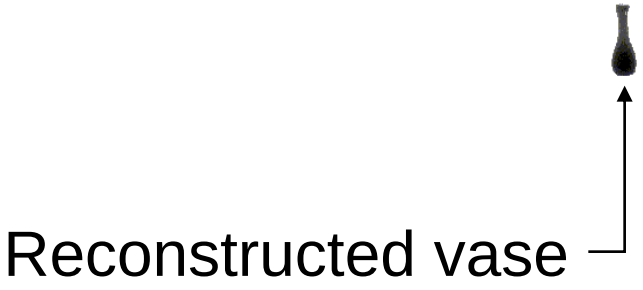


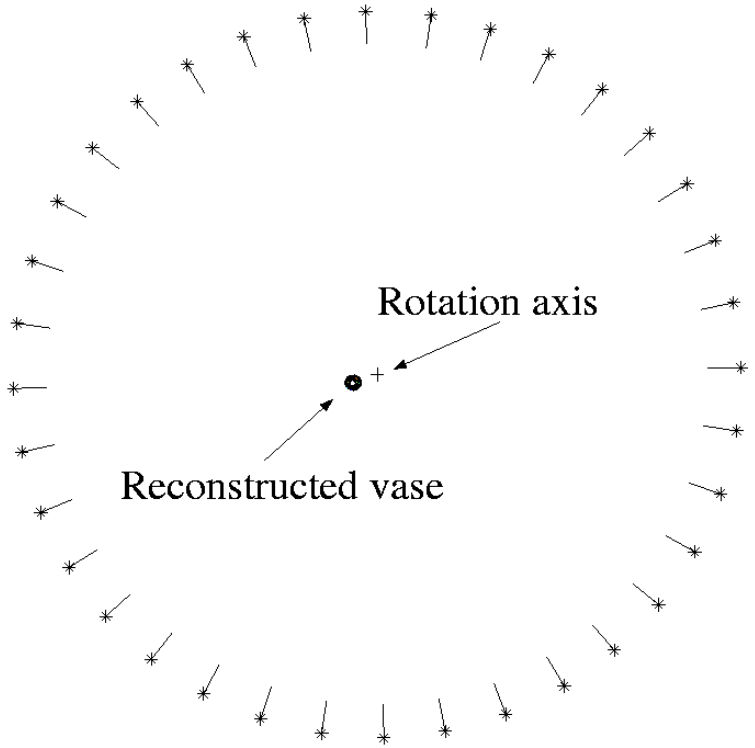


The cameras are constrained to follow a circular path.

# Circular motion

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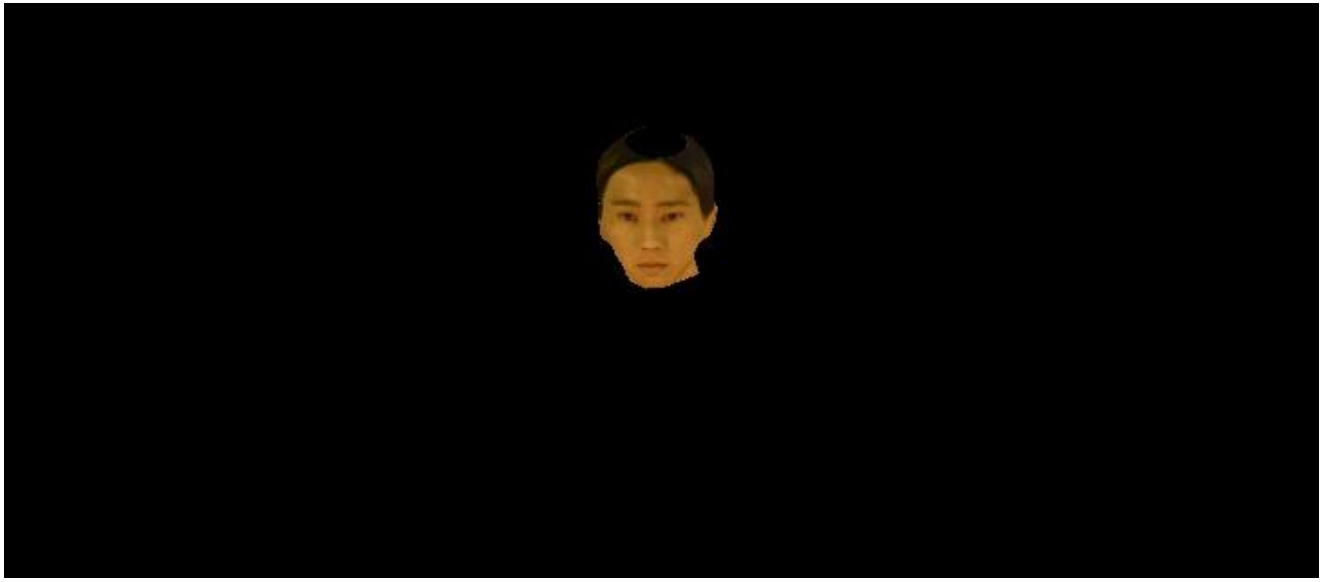

# Space-carving

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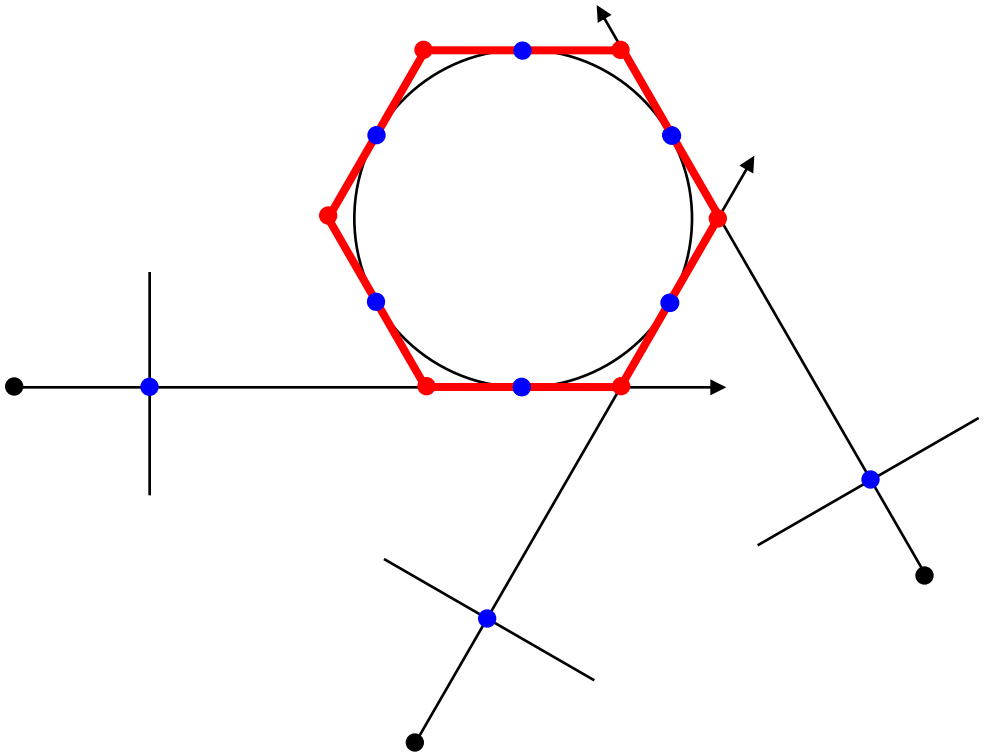

# Reconstruction by carving

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# Circular motion is insufficient

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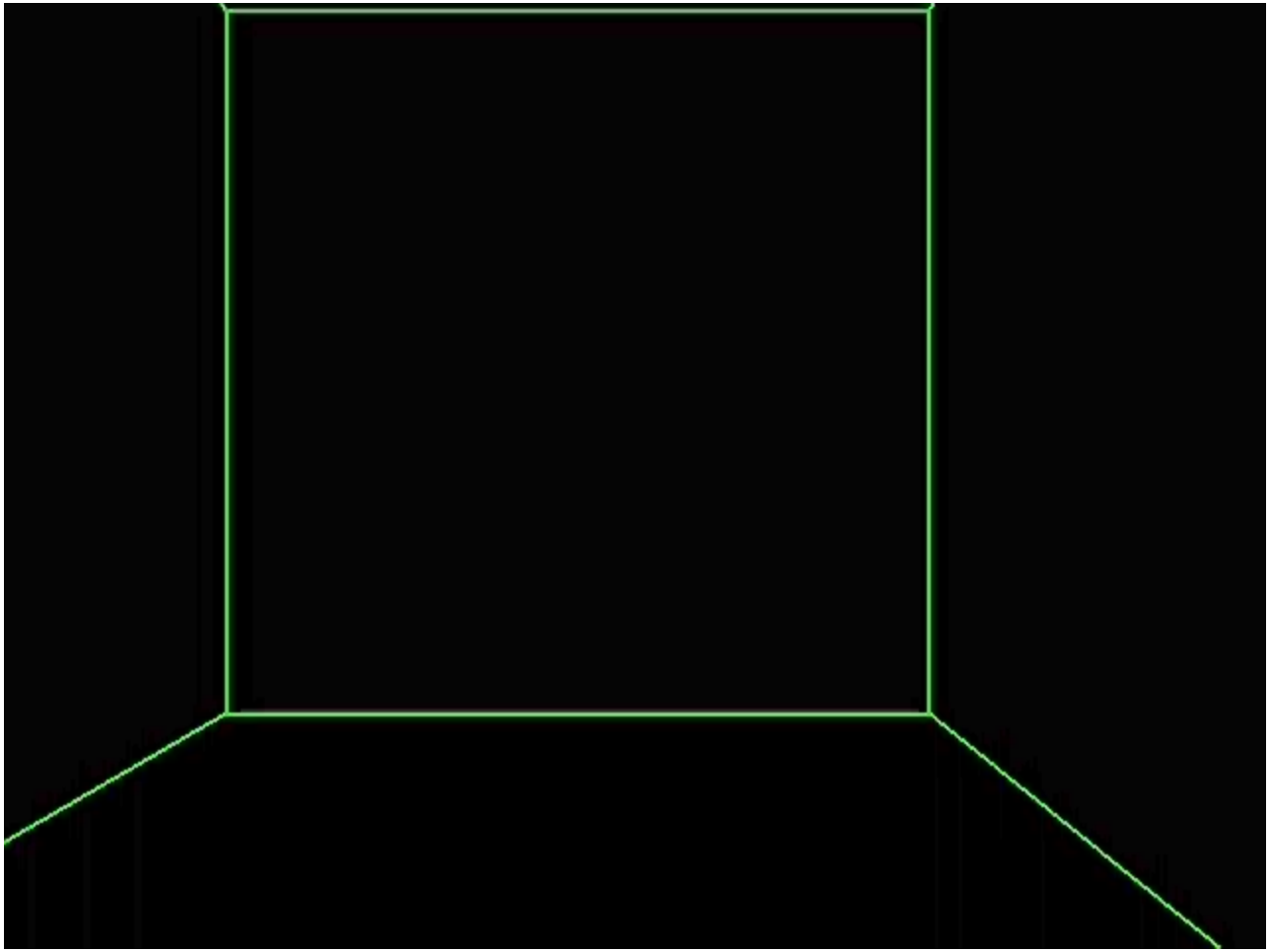

# Add arbitrary views

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# General motion constraints

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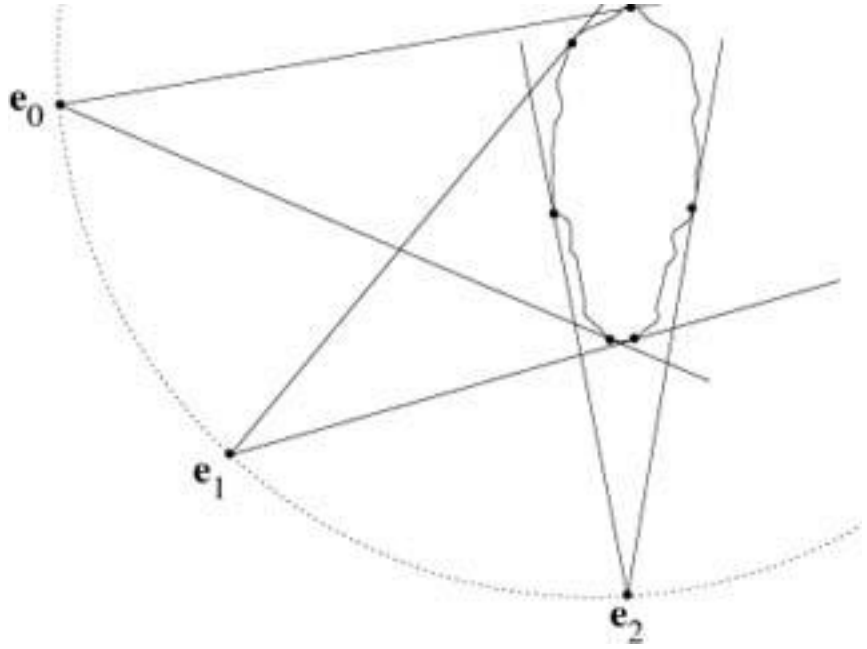

# Estimate general motion

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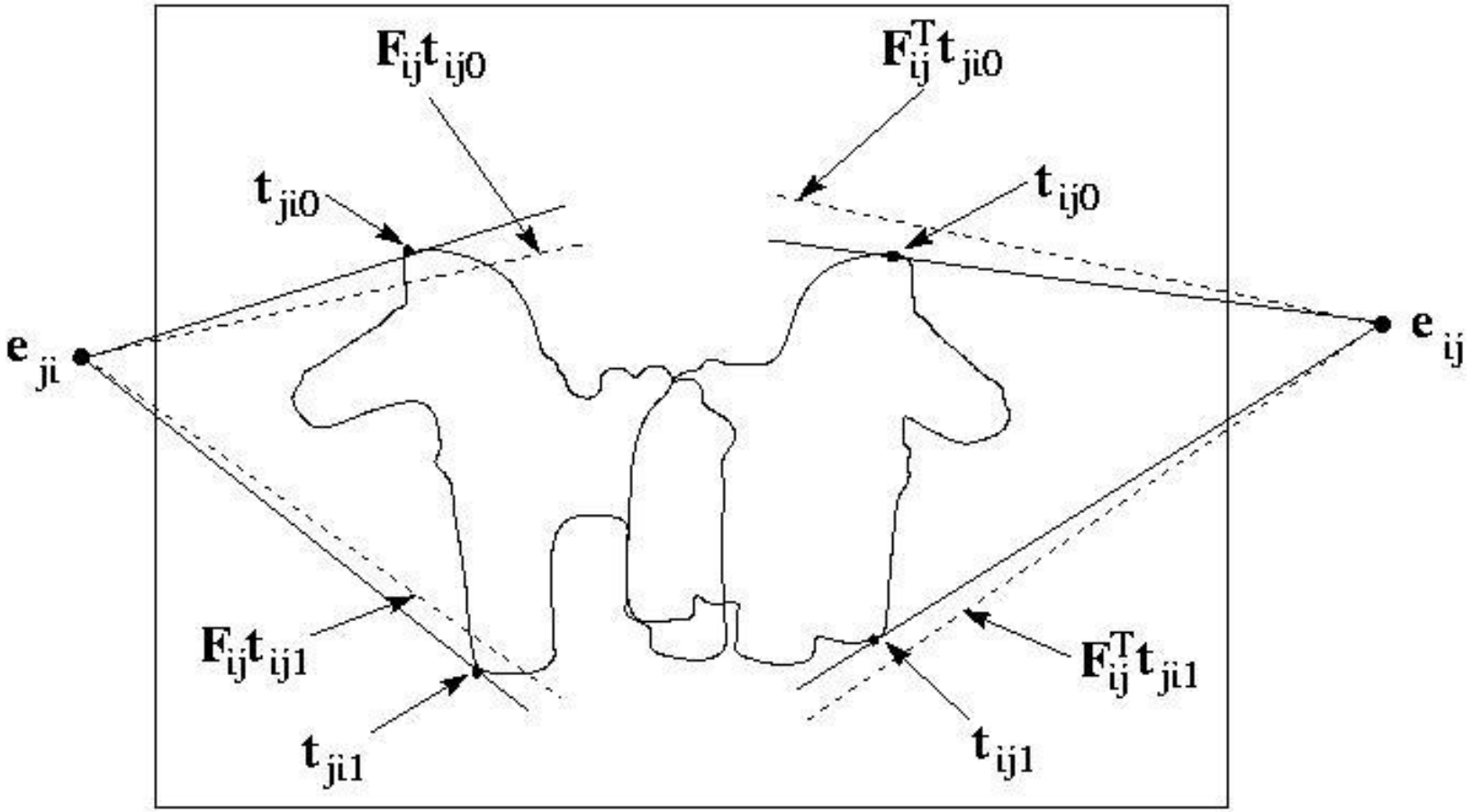

# Incrementally improve model

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# Summary

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- Requires only silhouettes.
- Recovery of motion and shape.
- Trivial initialisations for all the optimisations.
- Low-dimension search space.
- Future work:
  - Use shading/stereo/texture to refine models.
  - Physics of reflectance
  - Statistical models for uncertainty